Application Note

Mastering Audio Performance with TAS58xx Family of Class-D Audio Amplifiers: A Comprehensive Guide for Bluetooth Speakers, TVs, Soundbar and Beyond

Nayeem Mahmud, Sebastian Muriel

ABSTRACT

The Texas Instruments TAS58xx family of Class-D audio amplifiers offers a high-performance design for a wide range of audio applications. This application note serves as a comprehensive guide for engineers and product designers seeking to select and implement the optimal TAS58xx device for Bluetooth speakers, televisions, and general audio systems. It details critical performance parameters such as power output, THD+N, and efficiency, alongside a thorough exploration of key features including advanced protection mechanisms, sophisticated tuning and audio processing capabilities (EQ, DRC, limiting), and EMI mitigation techniques. Through comparative analysis of available devices and application-specific recommendations, this document leverages TI's innovative Class-D technology and supporting tools to empower developers to achieve superior audio quality and design robust and efficient systems.

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1 Introduction

Texas Instruments' (TI) TAS58xx family of Class-D audio amplifiers represents a leading-edge solution for demanding audio applications. Offering unparalleled efficiency, compact size, and exceptional audio fidelity, the TAS58xx series is revolutionizing the audio landscape. This application note provides a comprehensive guide to selecting the optimal TAS58xx amplifier for diverse applications, specifically focusing on Bluetooth speakers, televisions, and general audio systems. This application note also dissects the critical parameters, considerations, and trade-offs involved in choosing the right amplifier, showcasing the unique strengths of TI's offerings. This guide aims to empower engineers and product designers to leverage the full potential of the TAS58xx family for superior audio experiences. This document builds on established industry best practices and highlights the innovative features unique to TI's Class-D technology.

2 Key TAS58xx Amplifier Parameters and Specifications

Several key parameters determine a TAS58xx amplifier's suitability for a given application:

- Power Output: The ability of the amplifier to deliver continuous power to the loudspeaker. TI offers TAS58xx devices ranging from lower-power designs preferred for portable speakers to high-power options for demanding home theater applications.
- Total Harmonic Distortion + Noise (THD+N): A measure of the distortion introduced by the amplifier. TAS58xx amplifiers consistently deliver exceptionally low THD+N levels, typically below 0.03% at 1W output, resulting in cleaner, more accurate audio reproduction.
- Signal-to-Noise Ratio (SNR): Indicates the level of unwanted noise relative to the desired audio signal. TAS58xx amplifiers achieve high SNR values, generally exceeding 100dB.
- Frequency Response: The range of frequencies the amplifier can reproduce accurately. TAS58xx amplifiers offer wide frequency responses for the audible spectrum (20Hz – 20kHz).
- Efficiency: The percentage of input power delivered to the loudspeaker. TAS58xx amplifiers boast efficiencies up to 90%, minimizing heat dissipation and maximizing battery life.
- Protection Features: TI's TAS58xx amplifiers incorporate a comprehensive suite of protection features, including Over-Current Protection (OCP), Cycle-by-Cycle Current Limit, Over-Voltage Protection (OVP), Over-Temperature Protection (OTP), Thermal Foldback, Short-Circuit Protection (SCP), DC Protection, PVDD Sensing, and so on.

3 Benefits and Key Features of TAS58xx Devices

3.1 Efficiency Feature: Class H

Class-H technology dynamically adjusts supply voltage (PVDD) based on real-time audio signal levels. The internal DSP of the amplifier analyzes the input signal and generates control signals via GPIO pins to modulate the boost converter output. This adaptive approach significantly improves efficiency, particularly beneficial for:

- Extending battery life in portable devices
- Reducing thermal dissipation
- Lowering power consumption during low-volume listening

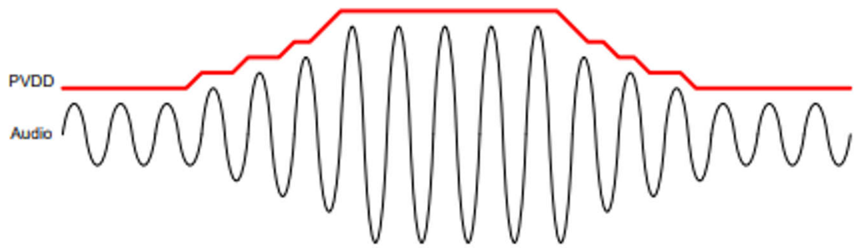

Figure 3-1. Class-H Architecture

Figure 3-2 and Figure 3-3 show how Class-H control dynamically adjusts the supply voltage (PVDD) based on the audio signal. When audio signals are small, PVDD remains low to minimize power losses. As signal levels increase, PVDD rises to provide adequate headroom without stressing the output stage. By minimizing the voltage differential between supply and instantaneous signal requirements, Class-H substantially reduces switching losses and improves overall efficiency.

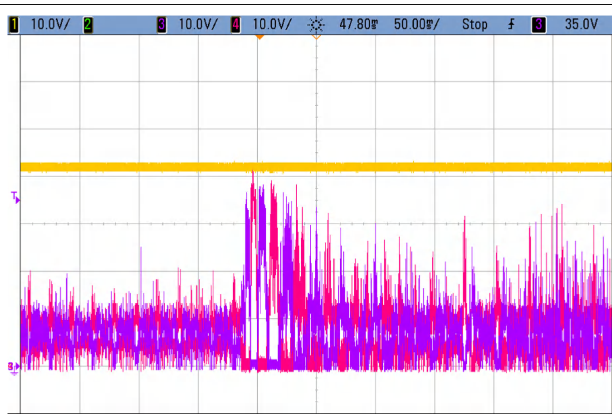

Figure 3-2. Audio Output and Boost Voltage Without Class-H Operation

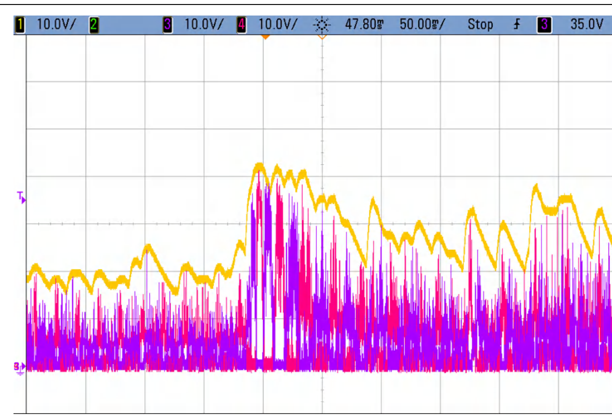

Figure 3-3. Audio Output and Boost Voltage With Class-H Operation

3.2 Modulation Schemes: 1SPW, BD, Hybrid

Class-D amplifiers take an audio input signal and create a PWM signal which is then amplified by the output stage. The method used to convert a continuous audio input signal into a PWM signal is referred to as a modulation scheme. A few common modulation schemes are BD, 1SPW and Hybrid. Different modulation schemes offer different benefits such as increased efficiency or better noise performance.

3.2.1 1SPW Modulation

The 1SPW mode alters the typical modulation scheme to achieve higher efficiency with a slight penalty in THD degradation and more attention required in the output filter selection. In Low Idle Current mode, the outputs operate at approximately 15-20% modulation during idle conditions. When an audio signal is applied, one output decreases, and one increases. The decreasing output signal rails to GND. At this point, all the audio modulation takes place through the rising output. The result is that only one output is switching during the bulk of the audio cycle. The lower DC offset reduces the ripple current through the LC filter, the amplifier supply current, reduces EMI, and minimizes power losses at idle. This scheme offers the best efficiency compared to the other modulation schemes.

3.2.2 BD Modulation

In this modulation scheme, the duty cycle of each output is changed such that the average content corresponds to the input analog signal. Each output is switching from 0 volts to the supply voltage. The OUTPx and OUTNx are in phase with each other with no input so there is little or no current in the speaker. The duty cycle of OUTPx is greater than 50% and OUTNx is less than 50% for positive output voltages. The duty cycle of OUTPx is less than 50% and OUTNx is greater than 50% for negative output voltages. The voltage across the load sits at 0 V throughout most of the switching period, reducing the switching current, which reduces any I2R losses in the load. This scheme offers the best performance compared to the other modulation schemes.

3.2.3 Hybrid Modulation

Hybrid Modulation is designed to minimized power loss without compromising the THD+N performance and is optimized for battery-powered applications. The key feature of hybrid modulation is the PWM duty cycle is dynamically adjusted based on the detected input signal level and the PVDD voltage. When the input signal levels are high, the output duty cycle stays at 50%. When the input signal level is low, the output duty cycle decreases gradually. At idle the output duty cycle goes to 10%. Hybrid modulation achieves ultra-low idle current and maintains the same audio performance level as the BD Modulation.

Table 3-1 and Table 3-2 list the comparison of different modulation schemes in terms of efficiency and performance.

Table 3-1. Performance Comparison

	1SPW	BD	Hybrid
Ultra Low Power	Best	Best	Best
Low Power	Good	Best	Better
High Power	Better	Best	Best

Table 3-2. Efficiency Comparison

	1SPW	BD	Hybrid
Ultra Low Power	Best	Better	Best
Low Power	Best	Good	Better
High Power	Best	Good	Better

Plots are shown below to compare performance (THD+N) and Efficiency (Idle Current) of the different modulation schemes discussed with TAS5825M.

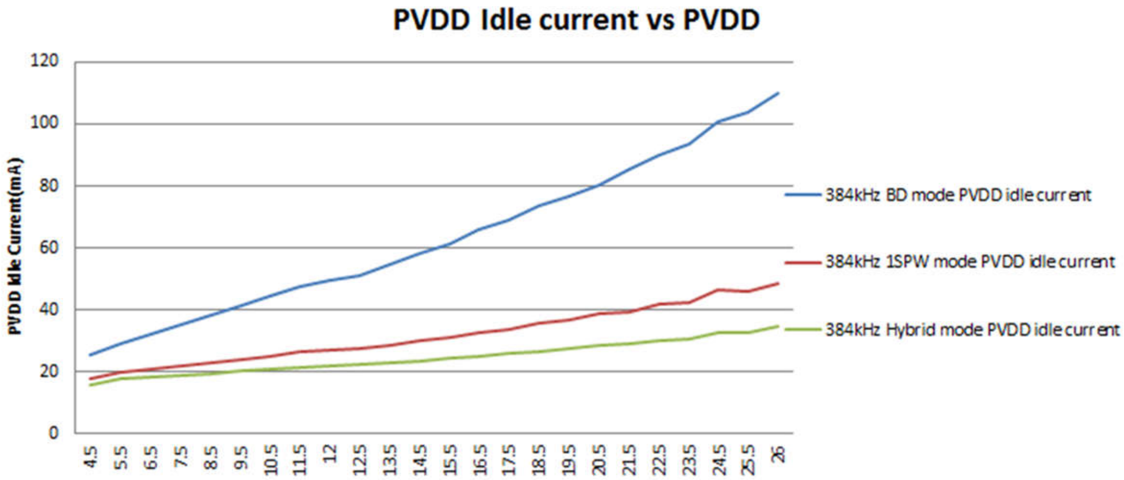

Figure 3-4. PVDD Idle Current vs PVDD

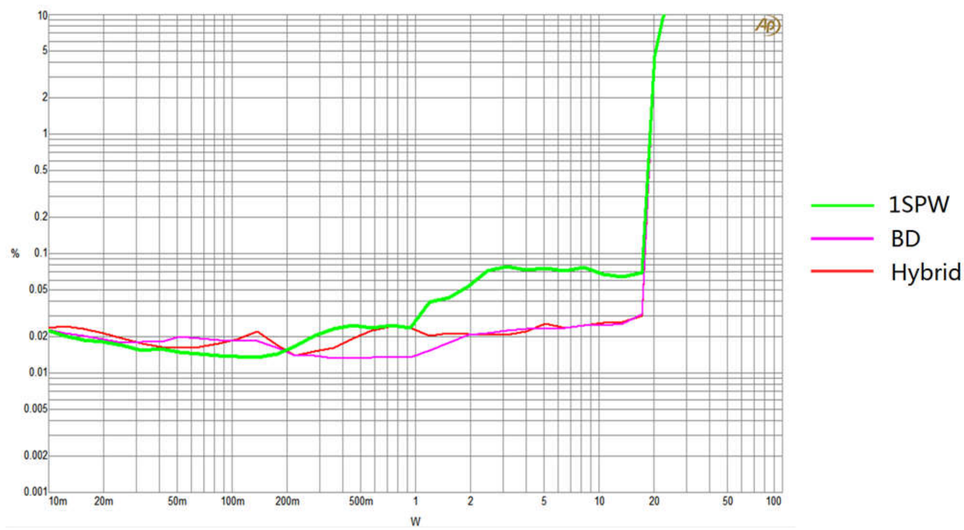

Figure 3-5. Comparisons of THD + N vs Output Power in BD, 1SPW and Hybrid Modes (PVDD = 18V, Load = 8Ω

3.2.4 Protection Features

TI's TAS58xx family offers modern protection features to avoid damage to speakers and the amplifier itself. Below is an overview of the common protection features offered. Below is an overview of the common protection features offered.

3.2.4.1 Over-Current Protection (OCP)

All TAS58xx devices have built-in over-current protection circuitry at the outputs. Each device will specify a typical over current protection threshold based on current capability of the internal clamp circuit. If the over-current threshold is exceeded the device will disable the Class-D output to avoid damage to the amplifier and the speaker. If an overcurrent event occurs, an overcurrent fault is reported at the corresponding register.

3.2.4.2 Cycle-by-Cycle Current Limit

Cycle-by-cycle current control limits the output current at each output FET during each switching cycle to prevent an undesired shutdown from tripping the overcurrent threshold. An immediate shutdown is triggered if the overcurrent threshold is tripped causing a latching shutdown.

3.2.4.3 Over/Under-Voltage Protection (OVP/UVP)

All TAS58xx devices have built-in over/under-voltage protection circuitry to avoid damage to the device during events such as power-up/down, surges or brownouts. In applications where the power rails of the amplifier are supplied from a battery the voltage can have large voltage swings.

3.2.4.4 Over-Temperature Protection (OTP)

Over-temperature protection is implemented on all of TI's TAS58xx devices. When the amplifier exceeds its specified over-temperature warning thresholds, the device risks going into over-temperature shutdown to avoid damage to the amplifier. If an over-temperature shutdown occurs, an over-temperature shutdown flag is reported at the corresponding register. In many applications an over-temperature shutdown is undesirable; this can be mitigated by the host with features such as thermal foldback.

3.2.4.5 Thermal Foldback

Most TAS58xx devices have a thermal foldback feature to reduce the digital gain as the device temperature increases into the over temperature warning range. This allows the device to cool down to prevent an undesired thermal shutdown.

3.2.4.6 Short-Circuit Protection (SCP)

All TAS58xx have pin-to-pin short protection at the outputs to prevent damage to the amplifier. During startup this short protection circuitry checks for a short at the outputs.

3.2.4.7 DC Protection

DC protection shuts down a channel if a DC offset above a defined threshold is seen at the output. This prevents damage to speakers which are sensitive to DC offsets in the case of an improper connection at the output.

3.2.4.8 PVDD Sensing

This feature reduces the gain depending on the measured value of the PVDD supply voltage to avoid clipping. This is most useful in scenarios where the customers have the volume turned up very high or there is a PVDD voltage drop due to the battery discharging.

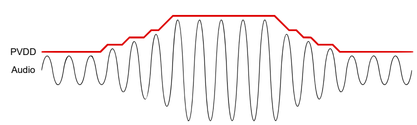

Figure 3-6. PVDD Sensing Example

3.3 Tuning and Audio Processing Blocks

TI's TAS58xx family includes many devices with an integrated DSP with fixed or configurable process flows, allowing the user to use limiting features to avoid clipping, configure parametric equalizers to get the most out of speakers where the natural frequency response is lacking, and more advanced audio processing features.

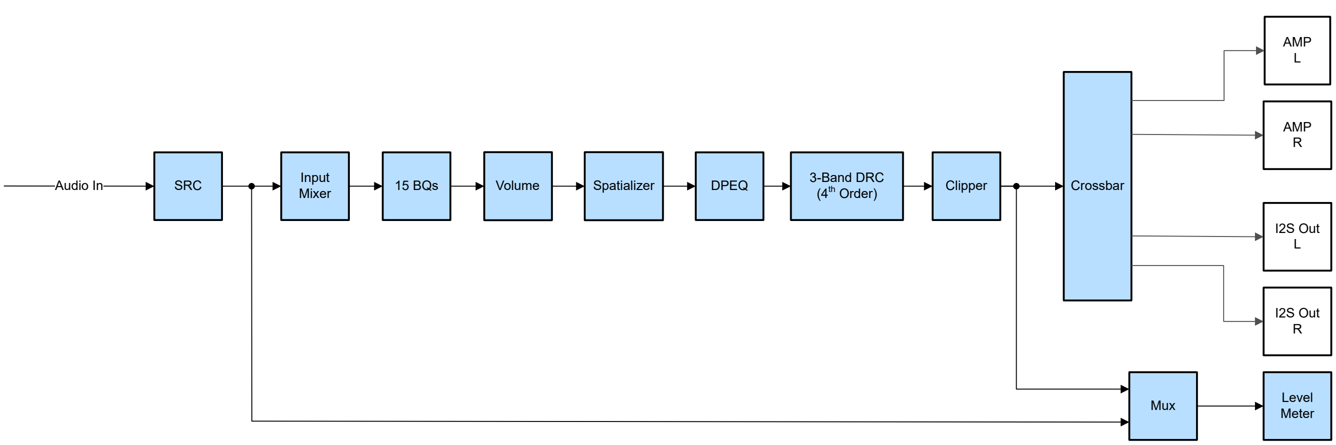

Figure 3-7. Typical Process Flow of TAS58xx Devices

3.3.1 Input Mixer

Provides flexible routing and mixing of left and right input channels according to application requirements.

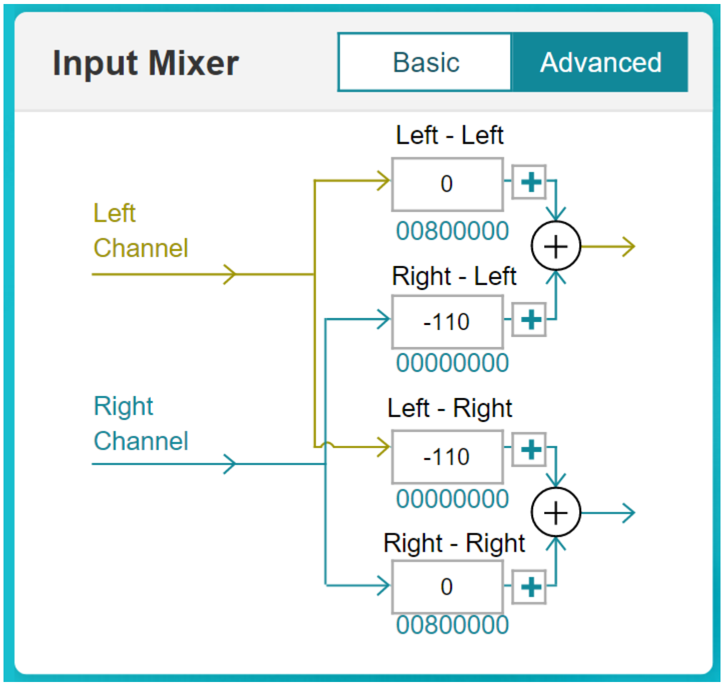

Figure 3-8. Input Mixer

3.3.2 Equalizer

The equalizer filters are used to make the loudspeaker response flat and to compensate for any non-linear distortion such as speaker rub-and-buzz. The equalizer filters consist of multiple biquad (BQ) filters allowing the following:

- Loudspeaker frequency response compensation
- Extend the bass response of the speaker
- Attenuate frequencies that produce high THD
- Remove dc signals or very low frequency signals that may cause speaker damage due to over excursion

TAS58xx family has as high as 15 BQs for some devices for both L/R channel which can be manually configured for tuning. Each filter can be programmed with different filter types (high pass, low pass, equalizer, and so forth) and with different parametric options (corner frequency, bandwidth, gain, Q-factor, and so forth).

3.3.3 DEPQ

Dynamic parametric equalizer allows a signal to be dynamically attenuated or amplified based on the signal level detected. The user can set a threshold low (dB) and threshold high (dB). When the averaged input signal is below threshold low, the signal goes through the low path biquads. When the signal is above threshold high. The signal goes through the high path biquads. When the signal is between these thresholds, the signal is mixed together by the dynamic mixer level.

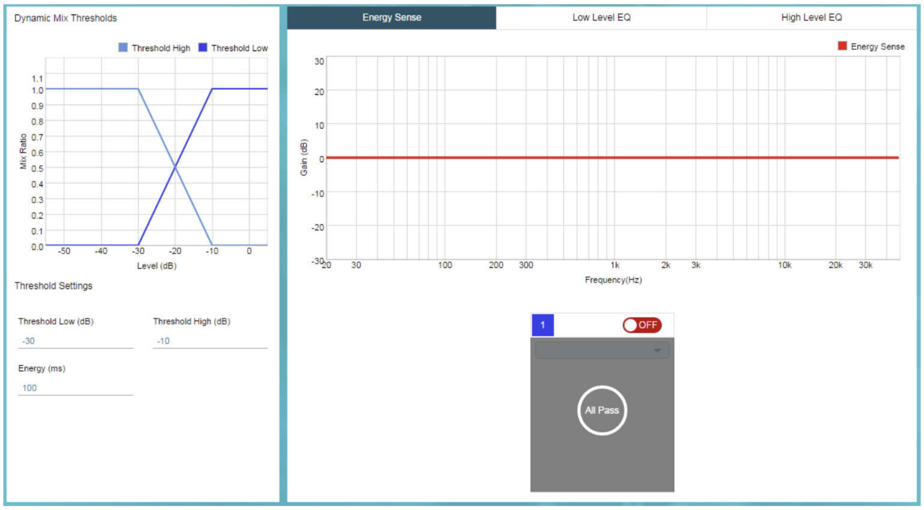

Figure 3-9. Dynamic Parametric Equalizer

3.3.4 3-Band DRC

The dynamic range compressor is a feature included in all TAS58xx devices which is used to limit the output signal above a certain programmable threshold. This is achieved by using a feed-forward mechanism that senses the audio signal level using an estimate of the alpha filter energy. DRC attacks (reduce gain) if the signal energy is above the threshold and releases once the energy of the audio signal falls below this threshold (increase gain).

Figure 3-10. Dynamic Range Compressor

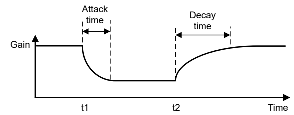

Figure 3-11. DRC Attack and Decay

3.3.5 Dynamic vs. Hard Limiting to Avoid Clipping

In many applications a limiter must be used to avoid harsh distortion at the outputs of the amplifier when trying to output a voltage above PVDD.

3.3.5.1 AGL

Automatic gain limiting is an enhanced DRC function available in many of the TAS58xx devices. AGL uses a feedback topology to compress an incoming audio signal if it is above the AGL threshold. A softening filter is used to remove harmonics during the compression. The attack/release times can be tuned to change how quickly an audio signal is compressed/released.

3.3.5.2 Limiter/Clipper

The limiter/clipper feature will clamp the output to a pre-determined peak voltage. This will produce a clipped waveform which will have higher distortion compared to a dynamic limiter like AGL.

3.3.5.3 Output Crossbar

The output crossbar allows the user to control the signal that appears on the left/right outputs and the I2S SDOUT.

3.4 EMI Features

3.4.1 Spread Spectrum

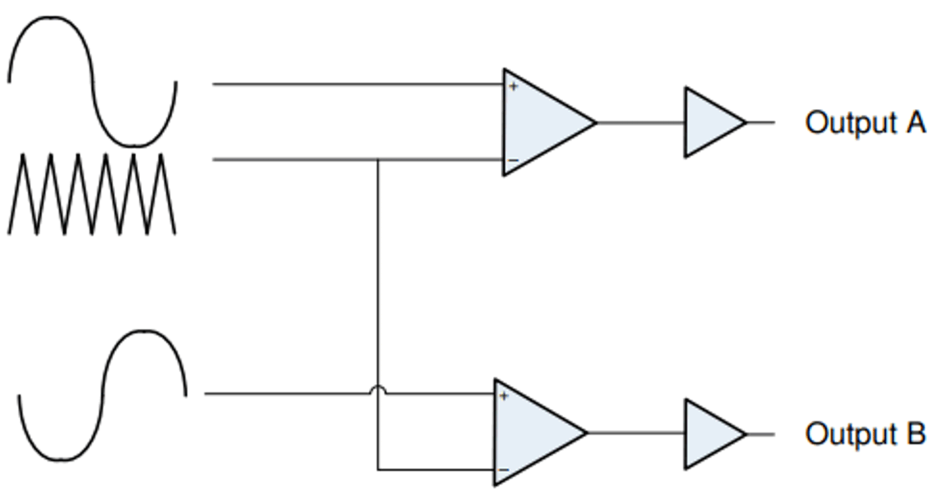

Figure 3-12. Class D Audio Amplifier

Figure 3-13 is an example of a typical BD modulation scheme in a fixed frequency mode vs spread spectrum mode. In the fixed frequency mode, there is an internally generated triangular waveform that goes to comparator which switches at a fixed frequency. The output PWM changes duty cycle to generate a moving average of the signal that corresponds to the input analog signal. In spread spectrum mode, the internally generated triangular waveform changes frequency cycle to cycle within a configured range of the center frequency. The varying of this triangular frequency spreads the energy of the across a larger bandwidth, lowering the spikes for radiated emissions results. This feature can lower spikes by up to several dB, making it simpler to pass radiated emissions limits.

Figure 3-14 is an example of the FFT between fixed frequency and spread spectrum modes to illustrate the reduced peaks of the spread spectrum scheme.

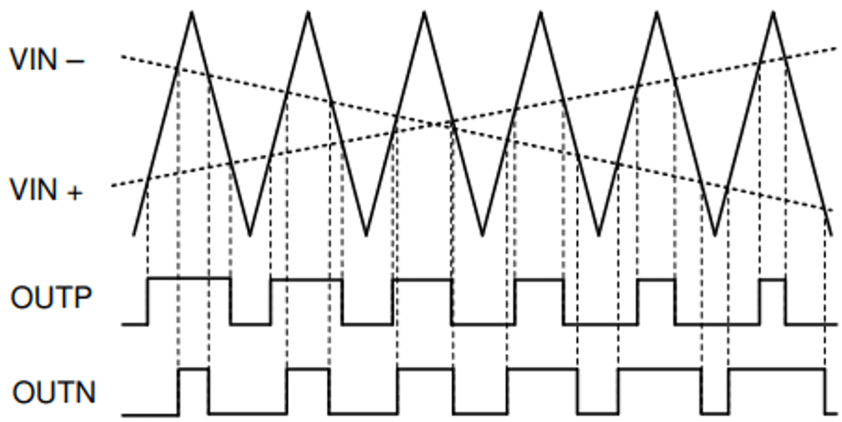

Figure 3-13. Spread Spectrum Mode Modulation

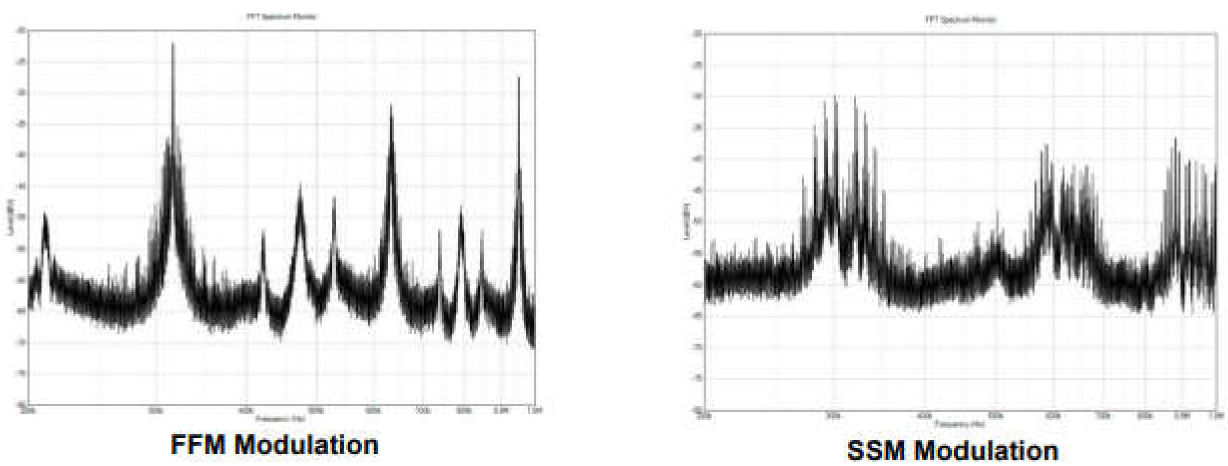

Figure 3-14. Difference between FFM and SSM Modulation

3.4.2 Phase Sync

The TAS58xx family also offers dephase circuits to improve conducted emissions. Our mid power amplifiers are often used in multi-channel applications such as soundbars or TVs where this feature can be beneficial. The dephase circuit interleaves the switching timing between channels. A phase shift of 45 degrees can be supported on most TAS58xx devices, allowing support for up to four devices. Since the different channels are switching out of phase, the output ripple current is reduced by half, which improves conducted emissions on the PVDD network.

4 Comparing Key TAS58xx Devices

The following table summarizes key specifications and features of the TAS58xx family:

Table 4-1.

Specification	TAS5802	TAS5805M	TAS5815	TAS5822	TAS5825M	TAS5825P	TAS5827	TAS5828M	TAS5830
PVDD Range	4.5-20V	4.5-26.4V	4.5-26.4V	4.5-26.4V	4.5-26.4V	4.5-26.4V	4.5-26.4V	4.5-26.4V	4.5-30V
Output Power (4Ω, 1% THD+N)	2×22W	2×23W	2×30W	2×35W	2×38W	2×38W	2×43W	2×50W	2×60W
Peak Current	5A	5A	7.0A	7A	7.5A	7.5A	8A	8A	8A
RDS(on) per FET	120mΩ	180mΩ	120mΩ	90mΩ	90mΩ	90mΩ	70mΩ	90mΩ	70mΩ
Efficiency (Typical)	91%	89%	90%	92%	95%	95%	91%	90%	92%
	(8Ω, 45W)	(8Ω, 30W)	(8Ω, 65W)	(8Ω, 70W)	(8Ω, 45W)	(8Ω, 45W)	(8Ω, 75W)	(8Ω, 80W)	(8Ω, 80W)
THD+N (1W, 4Ω, 1kHz)	0.03%	0.06%	0.03%	0.02%	0.03%	0.03%	0.05%	0.08%	0.015%
SNR (A-weighted)	108dB	107dB	110dB	110dB	110dB	110dB	110dB	110dB	110dB
Class-H Support	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
PVDD Sensing	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Thermal Foldback	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cycle-by-Cycle CBC	No	No	No	No	Yes	4-Step	4-Step	4-Step	4-Step
Hybrid Modulation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
EQ Band	2×15 BQs	2×15 BQs	2×15 BQs	2×14 BQs	2×15 BQs	2×15 BQs	2×12 BQs	2×12 BQs	2×15 BQs
DRC Bands	3	3	3	2	3	3	3	4	5
AGL (Auto Gain Limiter)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DPEQ	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Supports 2.0 (Stereo)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Supports 1.0 (PBTL)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Supports 1.1 (Mono)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Package Type	28-PWP	28-PWP	28-PWP	38-DCP	32-RHB	32-RHB	32-RHB	32-DAD	32-DAD
Package Size	4.4×9.7mm	4.4×9.7mm	4.4×9.7mm	4.4×9.7mm	5×5mm	5×5mm	5×5mm	6.1×11mm	6.1×11mm
Thermal Pad	PadDown	PadDown	PadDown	PadDown	PadDown	PadDown	PadDown	PadUp	PadUp
Target Applications	Entry BT Speakers/TV	Entry BT Speakers/TV	Entry BT Speakers/TV	Soundbars, Premium TV	Soundbars, Speaker	Soundbar, BT Speakers	Soundbar, BT Speakers	Premium Soundbar, Speakers	Premium Soundbar, Speakers
Typical Price Point	$	$	$	$$	$$	$$	$$	$$$	$$$

5 Application-Specific Requirements

The first step in amplifier selection is clearly defining the requirements of the target application. Let's categorize common applications and their key considerations:

5.1 Bluetooth Speakers

- Power Output: Typically ranges from 1W to 50W per channel, depending on speaker size and intended use (ultra-portable, bookshelf, party speaker).
- Battery Life: Critical for portable speakers. High efficiency is paramount to maximize playtime.
- Size & Weight: Small form factor and light weight are essential for portability.
- Audio Quality: Low distortion and wide dynamic range are desired for a pleasant listening experience.
- Features: Bluetooth connectivity, multi-speaker pairing, waterproof/dustproof ratings.
- Cost Sensitivity: Bluetooth speakers are often highly price-competitive.

5.2 Televisions and Soundbars

- Power Output: From 10W to 100W per channel, dictated by TV size and desired volume levels. Soundbars often fall in this category.
- Sound Quality: Clear dialogue reproduction and immersive surround sound are crucial.
- Total Harmonic Distortion + Noise (THD+N): Must be low to avoid audible distortion, especially at higher volumes.
- Dynamic Range: Important for reproducing the full spectrum of sound effects and music.
- Space Constraints: Thin TV designs necessitate compact audio solutions.
- Digital Audio Input Support: Compatibility with various digital audio formats.

5.3 General Audio Applications (Home Stereo, Gaming, and so on)

- Power Output: Highly variable, ranging from a few watts for headphones to hundreds of watts for high-end home theater systems.
- Audio Fidelity: Primarily determined by the THD+N, SNR (Signal-to-Noise Ratio), and frequency response of the amplifier
- Control Features: Volume control, tone adjustments, source selection.
- Budget: Can range from budget-friendly to high-end audiophile solutions.

6 Application-Specific Recommendations: Utilizing TAS58xx

6.1 Bluetooth Speakers

- Prioritize: Efficiency, small size, low distortion, and battery life.
- Recommended ICs: TAS5802, TAS5805, TAS5815
- Power Output: 5W - 30W per channel.
- Design Considerations: Minimize component count and optimize for low quiescent current.

6.2 Television and Soundbars

- Prioritize: Low THD+N, wide dynamic range, and compact size.
- Recommended ICs for TV: TAS5802, TAS5805, TAS5815, TAS5815, TAS5822.
- Recommended ICs for Soundbar: TAS5822, TAS5825, TAS5827, TAS5830.
- Power Output: 10W - 100W per channel.
- Design Considerations: Implement robust power supply filtering and optimize for low EMI.

6.3 General Audio (Home Stereo, Gaming)

- Prioritize: Audio fidelity, power output, and input flexibility.
- Recommended ICs: TAS5802, TAS5815, TAS5822P, TAS5805M (depending on power requirements).
- Power Output: Dependent on speaker system; can range from 20W - 200W per channel or higher.
- Design Considerations: Implement high-quality output filters and verify proper heatsinking for high-power applications.

7 PCB Layout Best Practices for TAS58xx

TI recommends following the EVM User's Guide or Schematics and Layout Guideline for a particular device which is available on ti.com. Here are some basic guidelines:

7.1 Ground Plane: Pad Up vs Pad Down

TI's TAS58xx devices must be connected to a heat sink via thermal pad that is either on the top (pad up) or bottom (pad down). Pad down devices offer the benefit of a smaller footprint with no external heat sink required. For superior thermal performance, pad up devices are recommended since an external heat sink is typically better at dissipating heat than thinner ground layers in a PCB stack up.

7.2 Trace Width

Select a trace width that can handle maximum continuous current flow for supply rails and the speaker outputs. For a standard 1oz /sq ft of copper, reference this IPC-2152 table. The user can calculate the max current flow at the outputs based on the maximum PVDD voltage, amplifier gain, and speaker impedance.

Table 7-1. Trace Width Requirements

Current (A)	Trace Width (mil)
1	10
2	30
3	50
4	80
5	110
6	150
7	180
8	220
9	260
10	300

7.3 Component Placement

Primarily, the goal of the PCB design is to minimize the thermal impedance in the path to those cooler structures.

- Avoid placing other heat producing components or structures near the amplifier (including above or below in the end equipment).
- If possible, use a higher layer count PCB to provide more heat sinking capability for the IC and to prevent traces and copper signal and power planes from breaking up the contiguous copper on the top and bottom layer.
- Place the IC away from the edge of the PCB when possible, to make sure that the heat can travel away from the device on all four sides.

7.4 Thermal Vias

- Remove thermal reliefs on thermal vias, because the thermal reliefs impede the flow of heat through the via.
- Vias filled with thermally conductive material are best, but a simple plated via can be used to avoid the additional cost of filled vias.
- Vias must be arranged in columns, which extend in a line radially from the heat source to the surrounding area.

8 Design Guidelines and Evaluation (TI Tools and Resources)

- Evaluation Modules (EVMs): TI offers EVMs for most TAS58xx devices, allowing for rapid prototyping and performance assessment: TAS5830EVM, TAS5828EVM, TAS5827EVM, TAS5825MEVM, TAS5825PEVM, TAS5822EVM, TAS5815PEVM, TAS5805EVM, TAS5802EVM.
- PPC3 Tools: PPC3 is TI's GUI for configuring our audio amplifiers registers. This tool allows for easy configuration of DSP features such as EQ and DRC as well as basic device settings.
- Application Notes & Whitepapers: TI provides over one hundred applications notes, application briefs and user's guide to assist customer in their audio integration process.
- TI E2E™ Community Audio Forum: TI E2E™ design support forums are an engineer's go-to source for help throughout every step of the design process.

9 Summary

Texas Instruments' TAS58xx family of Class-D amplifiers provides a compelling design for a wide range of audio applications. By carefully considering application requirements, understanding the key specifications of each device, and following the design guidelines outlined in this application note, unlock the full potential of TI's technology and achieve exceptional audio performance, efficiency, and reliability. Leveraging TI's extensive resources and support network further streamlines the development process and verifies a successful outcome.

10 References

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2. Texas Instruments, *TAS5805M 23-W, Inductor-Less, Digital Input, Stereo, Closed-Loop Class-D Audio Amplifier with Enhanced Processing and Low Power Dissipation*, datasheet.
3. Texas Instruments, *TAS5815 30-W, Digital Input, Stereo, Closed-loop Class-D Audio Amplifier with 96 kHz Enhanced Processing*, datasheet.
4. Texas Instruments, *TAS5822M 35-W, Digital Input, Stereo, Closed-Loop Class-D Audio Amplifier with 96kHz Enhanced Processing*, datasheet.
5. Texas Instruments, *TAS5825P 4.5 V to 26.4 V, 38 W Stereo, Digital Input, High Efficiency Closed-Loop Class-D Audio Amplifier with Hybrid-Pro Algorithm*, datasheet.
6. Texas Instruments, *TAS5825M 4.5 V to 26.4 V, 38-W Stereo, Inductor-Less, Digital Input, Closed-Loop Class-D Audio Amplifier with 192-kHz Extended Audio Processing*, datasheet.
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